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Effect of Concrete Compressive Strength on Performance of Fibrous Reinforced Concrete Corbels

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ABSTRACT

This paper presents an experimental investigation to study the behavior of fibrous high strength concrete corbels under the effect of static load. Totally six specimens with clear span to depth ratio equal to (0.7) were tested to failure. Three of the specimens provided with normal strength concrete with three different amounts of steel fibers (0%), (1%) and (2%) of total volume and three specimens provided with high strength concrete with same different ratios of steel fibers. The influence of concrete strength on the ultimate capacity, cracking capacity, load-deflection behavior, failure pattern and stiffness has been studied. Test results indicate that, the corbels with normal and high strength concrete were failed in diagonal shear mode. Also, the results showed that, the high strength concrete specimens generated higher ultimate capacity, cracking capacity, and stiffness than normal strength concrete.

KEYWORDS: ***Corbels, high strength concrete, normal strength concrete, shear failure, ultimate capacity.***

1. INTRODUCTION

The quickly development in concrete technology and the availability of concrete admixture both mineral and chemical admixtures leads to use the high-strength concrete in an important structural members such as bridges and high-rise buildings. High-strength concrete goes on better than conventional strength concrete. High-strength concrete provides large savings associated with the cost of materials and reduction of dead loads could lead to decrease the size of structural members for compression members. High strength concrete provides additional advantages associated with improved performance such as lower deflections as compared with conventional strength concrete because of high strength concrete provides increasing in elastic modulus and decreasing in creep. Also, an increase in the service life of the structure and significant reduction of the maintenance requirements can be achieved due to the superior durability of high-strength concrete (KIM, S. 2007).

Steel fibers reinforced concrete is important as it plays a part in developing of modern concrete technology, hence it represents a new construction concrete. Lately, efforts have been exerted in recent literatures to explore the ability of using (SFRC), chemical and mineral admixtures in producing high strength steel fiber reinforced concrete. Anyway, very limited studies were publishing in spite of the powerful demand and an effective importance of high strength steel fiber reinforced concrete in many special applications (Salih, S. A. et. al 2005).

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The fibrous high strength concrete used to improve the performance of various structural members such as beam, columns and slabs. Various studies were conducted on improving the structural performance of reinforced concrete beams by using fibrous high strength concrete (Sudheer Reddy L. et. al 2011), (C. N. Sushma et. al 2016), (Hamid Pesaran Behbahani 2010) and (Qiaoyan Guan et. al 2013). These studies concluded that the ultimate capacity, cracking capacity, deflections and ductility were enhanced when using fibrous high strength concrete in comparison with normal strength concrete. Also, the structural behavior of fibrous high strength concrete slabs was studied by (Ali H. Aziz et.al 2013), (Zeinab Tazaly 2012), (M. Shevatkar and B. K. Kolhapure 2013) and (Vasant B. 2013). They concluded that the increasing the compressive and tensile strengths of concrete is effective in increasing the ultimate and cracking capacities in addition to change in failure pattern from brittle failure to ductile failure. The strength characteristics of columns was studied when using fibrous high strength concrete by (Muhammad N. S. Hadi 2007), (Russell Burrell 2012), (Suheil Mazhari 2013) and (Muhammad N. S. Hadi 2000), the ultimate and cracking strengths were improved in comparison with normal strength concrete specimens. In this study, the structural behavior of fibrous high strength concrete corbels has been discussed through studying the load versus deflection behavior, failure pattern, ultimate capacity, cracking capacity and stiffness resulting from addition of steel fibers to high strength concrete.

2 DETALIS OF SPECIMENS GEOMETRY AND REINFORCEMENT

The experimental work includes casting and testing six corbels specimens with (250mm x 150mm x 250mm) of (depth x width x span) dimensions respectively. The shear span to depth ratio is (0.7), the area of steel is kept constant and all specimens are subjected to vertical load only. The reinforcement details and the corbels dimensions are shown in Figure 1.

3 MATERIALS AND METHODS

3.1 Concrete compressive strength ($f'c$)

Standard (150 mm x 300 mm) concrete cylinders and concrete cubes (150 mm3) are tested according to (BS1881:part116 1983) to perform the concrete compressive strength test at age of 28 days. The concrete mixes are divided into six groups, the compressive strength of six mixes used in this study are illustrated in Table 1.

3.2 Splitting tensile strength (ft)

Standard (150 mm x 300 mm) concrete cylinder are cast and tested according to (BS 1881:part117 1983) to determine the splitting tensile strength of concrete, see Table 1.

3.3 Flexural strength (fr)

According to (ASTM C78 2014) , standard (100*100*500) mm3 prisms are used to perform the flexural strength test (modulus of rupture test), see Table 1.

3.4 Static modulus of elastisity (Ec)

According to (ASTM C469 2014), it has been used the chord-modulus method to calculate the corbels modulus of elasticity by drawing a diagram between the stress and strain of loaded axially cylinder, see Table 1.

3.5 Fine aggregate

The sand specifications are smooth, rounded and have the fineness modulus of (2.69).The requirement of mixing is achieved by using only the passing sand from the sieve (4.75mm).

3.6 Coarse aggregate

Crushed gravel of maximum size 14 mm is used.

3.7 Super-plasticizer

High workability needed to produce the high strength concrete can be achived by using superplasticizer (high water reducing agent (HWRA).

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Commercially, it is known as "Glenium 51" based on polycarboxylic ether.

3.8 Steel fibers

Hooked end steel fibers are used with different volume fractions of (Vf= 1.0% and 2.0%) of concrete volume. The steel fibers dimensions are around 50mm length and 0.5 mm diameter with aspect ratio of 100.

4 RESULTSAND DISSCUSIONS

4.1 General behavior and failure pattern

At the initial stages of loadings, the flexural rigidity of all tested specimens seems high; the specimens show large resistance against applied loads. During increase the applied load, first crack appears at the corbel to column connection zone. The high strength concrete corbels have a vertical displacement less than the vertical displacement of normal strength concrete corbels; this gives an indication on large stiffness of high strength concrete specimens.

The post-cracking stage was characterized by reduction in specimens stiffness which resulting from an increasing the length and width of cracks, the deflection readings increased more rapid than previous stage. The vertical displacement of high strength concrete specimens is still less than the vertical displacement of normal strength concrete specimens.

At advanced stages of loading, a diagonal shear cracks initiate at the supports and extend towards the column face with an inclination angle about (60°), the width of cracks increases rapidly until failure of the specimens by diagonal shear pattern, see Figure 2 to Figure 7.

4.2 Load-deflection response

The loads versus deflection curves give an indication on progressive stages of specimen deterioration through the transformation of the behavior from elastic to plastic behavior stage until failure. The load versus deflection relationships for tested corbels are plotted in Figure8, Figure 9 and Figure 10. The first part of load-deflection curve represents the elastic case of the specimens; it starts at the beginning of loading until appearing of first cracks. At this point, the applied load exceeded the cracking capacity of the specimen. The pre-cracking stage is characterized by good response to applied load through small deflections readings.

After crack appearance, there is also linear relationship between load and deflection but the slope of the curve reduced a sign of decrease the stiffness of the specimens, the second linear stage extend until yielding of longitudinal steel bars.

The third part of load versus deflection curves starts after yielding of longitudinal steel bars until failure of tested specimens. This part of load versus deflection curve is non-linear. This stage characterized by lack the large part of specimen stiffness.

4.3 Effect of compressive strength on ultimate capacity

The main parameter that effects on capacity of specimens is the compressive strength of concrete in addition to other parameters such as section dimensions and reinforcement ratio. In this study, the positive effect of compressive strength can be clearly seen through comparison the specimen C4, C5 and C6 which have the percentage of increasing about 33.334%, 13.392% and 31.818% with references specimens C1, C2 and C3, see Table 2.

The increasing of the ultimate capacity is attributed to increase the neutral axis depth of the section result an increasing the internal resistance of the section.

4.4 Effect of compressive strength on cracking capacity

The improvement of cracking capacity significantly increased when increasing the compressive strength of concrete through increasing the flexural stiffness

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of the member which delays the appearance of first crack.

The amount of improvement is about 13.636%, 25.925%, and 23.529% for specimens C4, C5 and C6 in comparison with reference specimens C1, C2 and C3 respectively, see Table 2.

4.5 Stiffness

Stiffness can be defined as the resistance of an elastic body to deformation by an applied force, and can be expressed as:

$k = F / \delta$

Where:-

k = stiffness (N/m, lb/in), F = applied force (N, lb), δ = extension (m, in)

The amount of reduction in the stiffness of the specimens until yielding is around 4.477%, 7.881%, 4.716%, 10%, 0.911% and 27.691%. While, the amount of reduction of the stiffness until failure is about 12.536%, 22.665%, 14.9%, 57.053%, 41.294% and 58.823 for specimens C1, C2, C3, C4, C5, C6 respectively, as indicated in Table 3.

The stiffness of the specimens gradually decreased from the first crack stage to yield stage, the decreasing of stiffness extended till failure. The loss of stiffness during load application is attributed to the appearance of cracks, lack of bonding between the concrete and steel bars and increasing the number, width and length of cracks through loading stages.

5. CONCLUSIONS

The following conclusions can be adopted from this study:

1. The failure of normal strength concrete corbels is more controlled (ductile) than the high strength concrete corbels.
2. The using of high strength concrete has not changed the failure type of tested corbels.
3. Increasing the concrete compressive strength will increase the ultimate loading capacity of corbels.
4. The cracking capacity is affected positively by increasing the compressive strength of specimens.

Table 1: Mechanical Properties of Concrete

Type of Concrete	Compressive Strength (MPa)	Tensile Strength (MPa)	Modulus of Rupture (MPa)	Static Modulus of Elasticity (MPa)
Normal Concrete	28	1.41	5.16	33205
High Strength Concrete	57	2.92	7.88	129159
Normal Concrete with Steel Fiber 1%	30.9	2.04	7.81	39422
High Strength Concrete with Steel Fiber 1%	61.5	3.97	11.09	140810
Normal Concrete with Steel Fiber 2%	29.6	2.89	10.24	44153
High Strength Concrete with Steel Fiber 2%	60	4.47	13.70	148312

Table 2: Effect of Compressive Strength on Ultimate Loading Capacity

Specimen No.	Ultimate Loading Capacity	Percentage of Improvement (%)	Cracking Capacity (kN)	Percentage of Improvement (%)
C1	225	---	110	---
C4	300	33.334	125	13.636
C2	280	---	135	---
C5	317.5	13.392	170	25.925
C3	330	---	170	---
C6	435	31.818	210	23.529

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Table 3: Amount of Reduction in Stiffness of Corbels.

Specimen No.	Stiffness (kN/mm)			Ratio of Decreasing (%) between Yield Stage and First Crack Stage	Ratio of Decreasing (%) between Fiailure Stage and First Crack Stage
	at First Crack	at Yield	at Failure		
C1	54.162	51.737	47.372	4.477	12.536
C2	86.206	79.412	66.667	7.881	22.665
C3	91.891	87.557	78.199	4.716	14.9
C4	245.1	220.588	105.263	10	57.053
C5	163.393	161.904	95.921	0.911	41.294
C6	214.285	154.946	88.235	27.691	58.823

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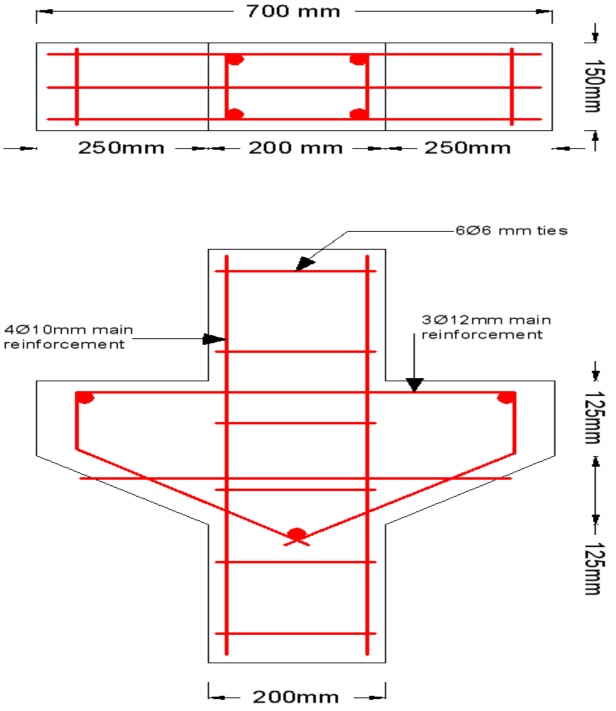

Figure 1: Description of Tested Corbels.

Figure 2: Failure Mode of Specimen (C1).

Figure 3: Failure Mode of Specimen (C2).

Figure 4: Failure Mode of Specimen (C3).

Figure 5: Failure Mode of Specimen (C4).

Figure 6: Failure Mode of Specimen (C5).

Figure 7:Failure Mode of Specimen (C6).

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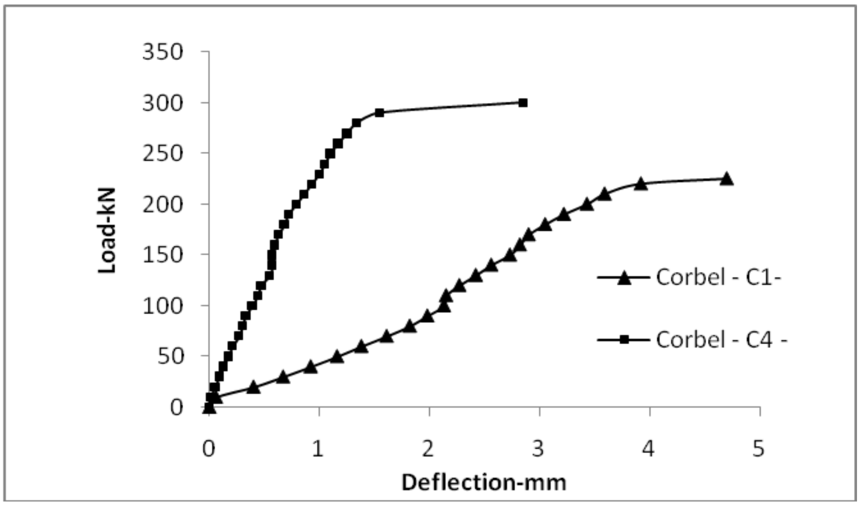

Figure 8: Load-deflection Curve of Specimens (C1) and (C4).

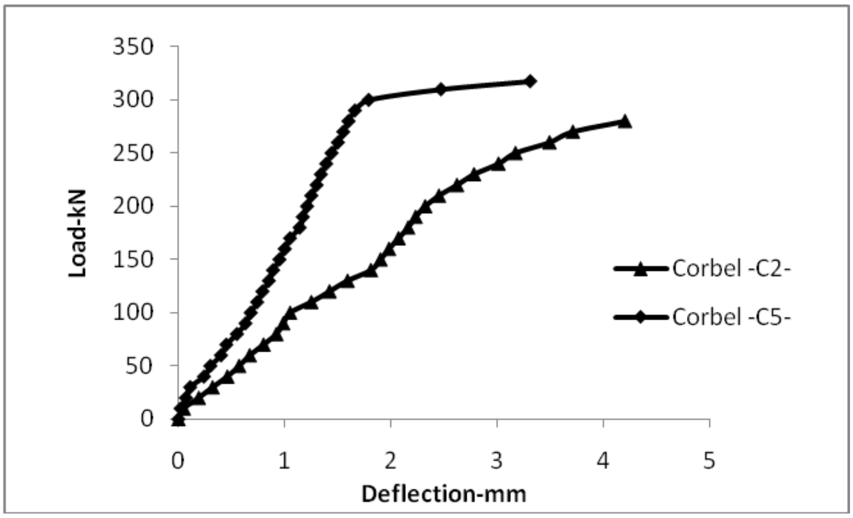

Figure 9: Load-deflection Curve of Specimens (C2) and (C5).

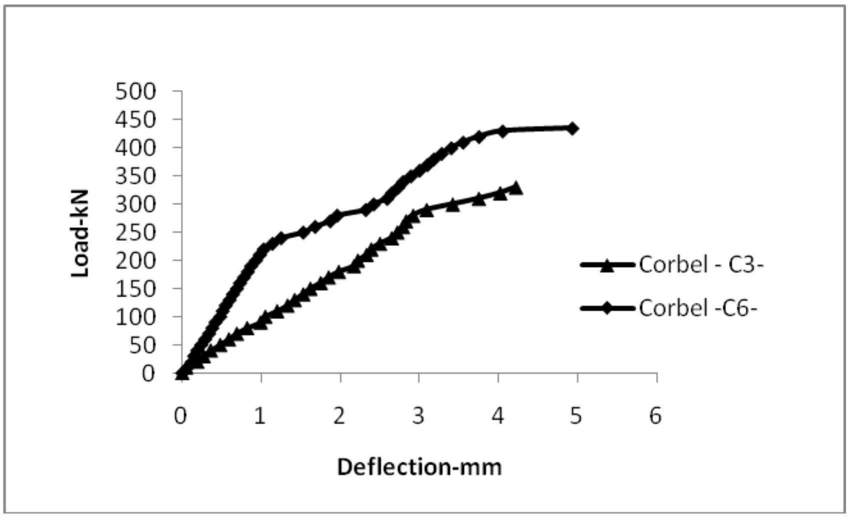

Figure 10: Load-deflection Curve of Specimens (C3) and (C6).

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